Aalto University
School of Engineering

Hafsa Ahmed Munia

The role of upstream water use on water stress in transboundary river basins: a global analysis

Master's thesis for the degree of Master of Science in Technology submitted for inspection, Espoo, 03 October, 2014.

Supervisor Assistant professor Matti Kummu

Instructor D.Sc. (Tech.)Yoshi Wada

MSc (Tech) Miina Porkka

Author Hafsa Ahmed Munia

Title of thesis The role of upstream water use on water stress in transboundary river basins: a global analysis.

Department Civil and Environmental Engineering

Professorship Water Resources Management **Code of professorship** Yhd-12

Thesis supervisor Ass. Prof. Matti Kummu

Thesis advisor(s) / Thesis examiner(s) D. Sc.Yoshi Wada, MSc Miina Porkka

Date 02.10.2014 **Number of pages** 26 **Language** English

Abstract

Upstream-downstream relationship remains one of the many challenges of transboundary water management. Water use of upstream countries has always impact on the downstream water availability and in some cases it might lead to increased water scarcity in downstream part of a basin. In this study, aim is to assess the change in water stress level due to water use of upstream countries in the world's transboundary river basins. Water stress level was first calculated considering only own water use of a sub-basin and this was then compared to the situation when both, own and upstream water use, were taken into account.

When only own water use was considered, 955 million people lived under water stress in world's transboundary river basins. When the upstream water use was taken into account, the population under water stress increased by 6 percentage points (194 million people). The stress increased most in Asia (central and north-east parts), Africa and some parts of Europe. Further, the results were compared with International water Event Database (1950-2008) by Oregon State University to assess whether there is a link between increased water stress due to upstream water use and the occurrence of conflictive and cooperation events in the transboundary river basins. Although no direct relationship between these two variables was found, in many basins with high number of events also the stress index increased considerably due to upstream water use.

In case of transboundary river basin management, one of the key challenges is allocating shared water resources, and their benefits. My findings are thus important for international water bodies where equitable water allocation is at the center of water conflicts.

Keywords Transboundary river basins, water stress, Upstream, Downstream.

Acknowledgements:

This study was carried out at the Water & Development Research Group of Aalto University. The research was funded by Maa- ja vesitekniikan tuki ry.

I would like show my gratitude to everyone who supported me throughout my thesis work. I would like to especially thank my supervisor Ass. Prof. Matti Kummu for his continuous support, encouragement and insightful comments. He has spent a lot of time instructing me how to write a paper, how to search for literature and how to work with the data. I am also grateful to Dr.Yoshi Wada, from the University of Utrecht for providing me with data and Miina Porkka for the help she has offered me along the way.

I would also like to show special gratitude to all the members of Water & Development Research Group for their encouragement and inspiration. I cannot imagine a better working environment than this. I am really considering myself lucky to get a chance to work here.

Finally, I thank my parents for their persistent affection and moral support throughout my whole life. Last but not the least important, I owe more than thanks to my husband and my son , for their continuous support, patients and encouragement throughout the period of my study. Further gratitude to my friends, family members, and everyone else who supported and inspired me during my study.

Hafsa Ahmed Munia

Espoo, October 3rd 2014

Contents

1. Introduction

Approximately 40 percent of the population of earth lives in rivers and lakes that comprise two or more countries (UN Water 2013). The existing 276 transboundary lake and river basins cover almost one half of the globe's land surface and 60 percent of global water flow (UN Water 2013). Transboundary fresh water resources pose predominantly challenging management problems as water resource users at all scale find themselves in direct competition. This in turn creates tension and might conflict over water allocation and supply (Giordano, Wolf 2013). In some cases upstream water use might lead to increased water scarcity in downstream part of the basin (Gikonyo 1997).

Water scarcity can be classified into two main categories- physical water scarcity and social water scarcity (Falkenmark, Berntell et al. 2007). Physical water scarcity arises because of scarce water resources, while social water scarcity caused by unbalanced power relations, poverty and related inequalities (Falkenmark, Berntell et al. 2007). Physical water scarcity can be further divided into water shortage and water stress. In this article, only water stress is considered. Water stress refers to difficulties in water use due to accessibility or mobilization problems (Rockström, Falkenmark et al. 2009). In 2005, approximately 3 billion people were living under water shortage (Kummu, M., Ward, P. J.,de Moel,H.,Varis,o. 2010). According to a report from MIT Joint Program, by 2050 more than half the world's population will live in water-stressed areas and about a billion or more will not have sufficient water resources (Schlosser, Strzepek et al. 2014, Schewe, Heinke et al. 2014)

Water is a vital and yet finite resource. Therefore, transboundary water issues have been identified as possible reason to stimulate international and interstate war (Wolf, Yoffe et al. 2003). One of the possible stimulants is the increased water stress due to transboundary impacts on water availability (Ravnborg 2004). However, the evidences of this direct causal relationship between water scarcity and international insecurity are rather selective, whilst there are more evidences where water scarcity leads people to cooperate (Wolf, Yoffe et al. 2003). In case of transboundary water interstate negotiations regarding water is rather complicated but it can be said that, any cooperative or conflictive events associated to internationally shared water bodies are generally concerning the distribution and use of resource management (Ravnborg 2004).

One of the traditional challenges in transboundary water management is upstream/downstream relationship (Moellenkamp 2007). It is obvious that any water use within a shared basin bound to create stress in some way for other possible users, and downstream countries, in this case, are constrained by natural asymmetries because of their relative position within the basin. Such as in Central Asia, where upstream countries Tajikistan and Kyrgyzstan act as water providing countries for the downstream regions Uzbekistan, Turkmenistan and Kazakhstan (Yuldasheva, Hashimova et al. 2010).

Another reason identified for upstream/downstream water stress is difference of interests among the ʼʼupstreamʼʼ and ʼʼdownstreamʼʼ country. A good example is again Central Asia, where the downstream countries need water for irrigation purposes and upstream countries for energy production. When construction of new hydro power plants is a matter of concern for the upstream region, it is lack of cooperation for the downstream region, as it would intensify the already difficult water supply situation over there (Shustov 2009).

Transboundary waters are also defined as highly political and ruled by power asymmetry (Jägerskog, Zeitoun 2009). For an example, building dams in Mekong River is an advantage taken by the upstream country China over the downstream countries (Mehtonen 2008) while in case of Ganges very powerful downstream country like India is taking the benefit by controlling the great bulk of its river flow over Nepal (Rahman 2005).Tension among upstream / downstream country will become even worse, as water withdrawal for all sectors is expected to grow in the future (World Water Vision 2000).

All these examples show asymmetry in access to water and growing demand for a limited resource, which increases the possibility to conflictive relationship among riparian countries. The relationship between upstream/downstream riparian is critical especially when upstream countries take advantages of their favored position within the basin by controlling the water resources available to the downstream riparian (Graversen, Heberger 2011). This increases the need for cooperation within transboundary basins.

The existing studies regarding transboundary basins have focused on mainly in international water relation and management practices (Brochmann, Gleditsch 2012, Giordano, Wolf 2013, Jägerskog, Zeitoun 2009, Wolf 1998, Wolf 1999, Wolf 2004, Wolf 2007). Overconsumption of water resources by an upstream country not only creates conflicts but also make the cooperation more challenging. One of the ways to identify the potential problems is to assess the impact of upstream water use on downstream water stress. So far, however, the impact of water use in transboundary context has been studied globally only on transboundary aquifers (TBA) ((Wada, Heinrich 2013).

Therefore, in this study my objective is to assess the impact of upstream water use on downstream water stress in world's transboundary river basins. In more specific, the aim of this work is to assess the water stress due to countries' own water use and then analyze how the stress level increases due to upstream water use. With such an analysis it is possible to identify the regions where water stress is intensified due to upstream water use. I also compare the water stress results to conflict and cooperation events. Such study will help negotiating the water extractions within a basin and adopting proper means of regulating water extraction in different parts of a basin.

2. Materials and Methods

2.1 Materials

The materials used for the study can be divided into four categories:

- Basin area data
- Water resource availability data
- Water consumption data
- Population density data

The data sources for each category are listed in Table 1 while the preparations of datasets used for the analysis are presented in the following sections.

Table 1Database used in the study

	Data	Year	Source	Description
Area Data	Basin area	1960-2010	Wada et al (2011,2013)	Global grid with 0.5° resolution
Water resource data	Discharge	1960-2010	Wada et al (2011,2013)	Monthly data at global grid with 0.5° resolution
Water consumption Data	Irrigation water use	2010	Wada et al (2011,2013)	Monthly data at global grid with 0.5° resolution
	Industrial water use	2010	Wada et al (2011,2013)	Monthly data at global grid with 0.5° resolution
	Domestic water use	2010	Wada et al (2011,2013)	Monthly data at global grid with 0.5° resolution
Population data	Population density data	2010	Hyde (2005) and IIASA	Global spatial data

2.1.1 Basin and sub basin area

In this study, basins area data was obtained from Wada et al (2011, 2013). The data were converted from vector to 0.5 degree raster data. Sub basins area (SBA) was obtained from the mesh of basins and country borders. For the mesh, the country borders were first aggregated to 0.5 degree raster data and then joined with the basin area data.

2.1.2 Water Resource Availability

In this study, to calculate the water availability, average annual discharge for each basin was calculated by using the 50 years (1960-2010) water discharge data. The water availability was assessed separately for each sub-basin by locating the cell with maximum discharge within the area of a sub-basin in question and using that as the total available water within that sub-basin. The natural discharge was used and thus upstream water use was not taken into account in this phase but later in the analysis (see Section 2.2.2).

Water discharge data were taken from PCR-GLOBWB (PCRaster Global Water Balance) hydrological model results at a spatial resolution of 0.5° (Wada et al 2011, 2013). PCR-GLOBWB is a theoretical, process-based water balance model, which in brief, simulates for each grid cell (0.5°×0.5° globally) and for each time steps (daily) the water discharge in two vertically stacked soil layers and an underlying ground water layer, as well as the water exchange between the layers and between the top layer and the atmosphere (rainfall, evaporation and snowmelt)(Wada, van Beek et al. 2013). The model runs with a daily time steps but simulated stream flow is evaluated per month for the period 1960-2010 (Wada, van Beek et al. 2013).

2.1.3. Water consumption Data

In this study, agricultural, domestic and industrial water use data for year 2010 were used to describe the total consumptive water use of a sub-basin in question. Water consumption data for these sectors were obtained from Wada et al (2011,2013) at monthly time steps on a 0.5° global grid. These values were then aggregated to SBA scale as annual consumptive values.

2.1.4. Population Data

Population density dataset for year 2010 was derived by combining HYDE dataset for year 2005 (Klein Goldewijk, Beusen et al. 2010) and IIASA population density data (Grübler, O'Neill et al. 2007)for year 2010 and are aggregated from 5 min to 0.5° resolution for each SBA.

2.2 Methods

2.2.1 Identifying Upstream and downstream countries

A river that crosses at least one international boundary is considered as a transboundary river (Afroz, Rahman 2013). In this study, upstream/downstream countries were identified by taking into account the minimum altitude of each sub-basin of a basin in question, the river network (World Data Bank II 1980) and transboundary fresh water dispute database (Oregon State University. 2007). For each sub-basin the upstream area was identified by merging together all the upstream sub-basins.

An example of a basin with three sub-basins is shown in Figure 1. Here, country A, B and C is sharing the same river basin where A is upstream to B and C, because of higher minimum altitude and rivers flowing from there to each downstream sub-basin. B is upstream to C and downstream to A because of similar criteria. So, B is identified as middle stream while C has been identified as the most downstream country because of its lower minimum altitude.

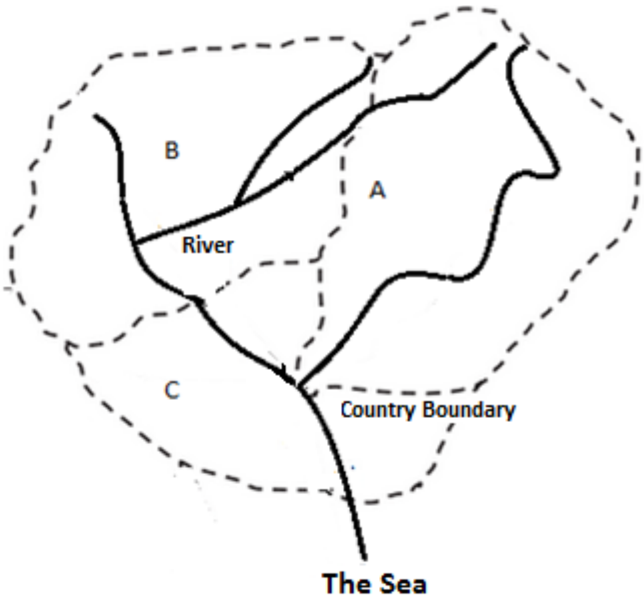


Figure 1Schematic upstream-downstream relationship in a river basin.

2.2.2 Water Stress Calculations

Water stress is the difficulty of obtaining fresh water for use during a period of time and may result in further depletion and deterioration of available water use (Rockström, Falkenmark et al. 2009). In this study, water stress is measured as a ratio of annual water consumption (D) to available water resources (A) (e.g. Falkenmark, 2007):

$$WSI = \frac{D}{A}$$

Water stress was first calculated for each sub-basin considering the available water resources for a sub-basin in question (see above Section 2.1.2) and its own water consumption. After that the upstream water use for each sub-basin was calculated and water stress was then calculated considering its own and upstream water use. In the case of upstream water use, water use of all the sub-basins upstream from a given sub-basin was taken in to account. At the end, I assessed the change in water stress level of each sub-basin due to upstream water use compared with situation with its only own water use.

I follow the thresholds of different levels of water stress defined by Falkenmark et al (2007):

- No stress zone: WSI<20%.
- Moderate stress zone: WSI = 20-40%.
- High stress zone: WSI= 40-70%.
- Extreme stress zone: WSI>70%.

3. Results

3.1. Upstream and Downstream countries

In this study, 222 transboundary basins larger than 10,000 km^2 and a total of 604 sub-basins were identified (Figure 2). Total of 141 countries are riparian to one or more of these international basins. These basins cover an area of 62 million square kilometers (110 million square kilometers of total land area). About 19% of total transboundary area is identified as upstream, 24% as middle stream and 57% are identified as downstream country. These basins inhabit altogether 2871 million people (59% of world's total population) in general (Table 2). In about 134 sub-basins, the upstream population is larger than the basin's own population whilst the opposite case in 458 sub-basins downstream population is larger than upstream population (Figure 3A).

Transboundary basins cover large part of Africa. In East Asia, for example, large part of the basins are within one country (e.g. in China). Many transboundary basins are also identified in Middle East, Central Asia and Southeast Asia, almost the entire Europe and some parts of North and South America (Figure 2).

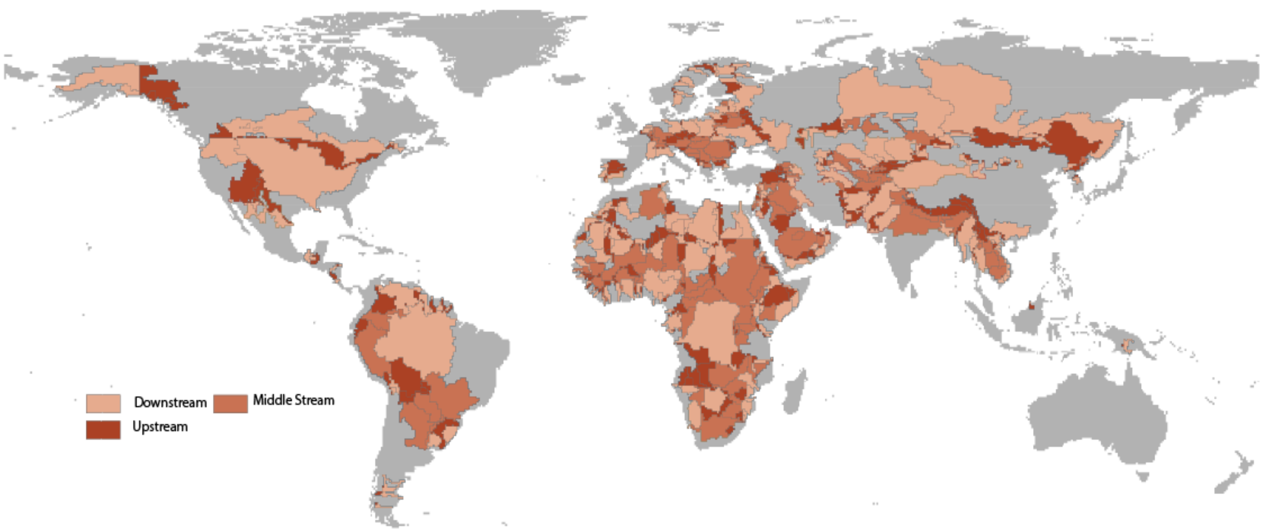


Figure 2 Identified upstream, middle stream and downstream countries.

Table 2 Facts about identified transboundary river basins.

	Upstream	Middle Stream	Downstream	Total
Area (million km^2)	12	15	35	62
Population (millions)	359	1233	1279	2871
Water use (km^3 /yr)	67	249	335	652
Water use per capita (m^3/cap/yr)	186	202	262	227

3.2. Water use

According to the calculations, agriculture is the most dominant water user in the transboundary river basin, accounting for the 76% of the total water consumption. Industrial and domestic water consumption constitutes 9% and 14% of the total water consumption respectively.

In average water consumption per capita was 262 km^3/yr for downstream countries while it was 202 m^3/yr and 186 m^3/yr for middle stream and upstream countries respectively (Table 2). About 199 sub-basins of total 604 sub-basins were identified where the basin's own water use was larger than one in upstream (Figure 3B), while in case of water use per capita, 160 sub-basins were identified where their own water use per capita was higher than the one in upstream sub-basins (Figure 3C).

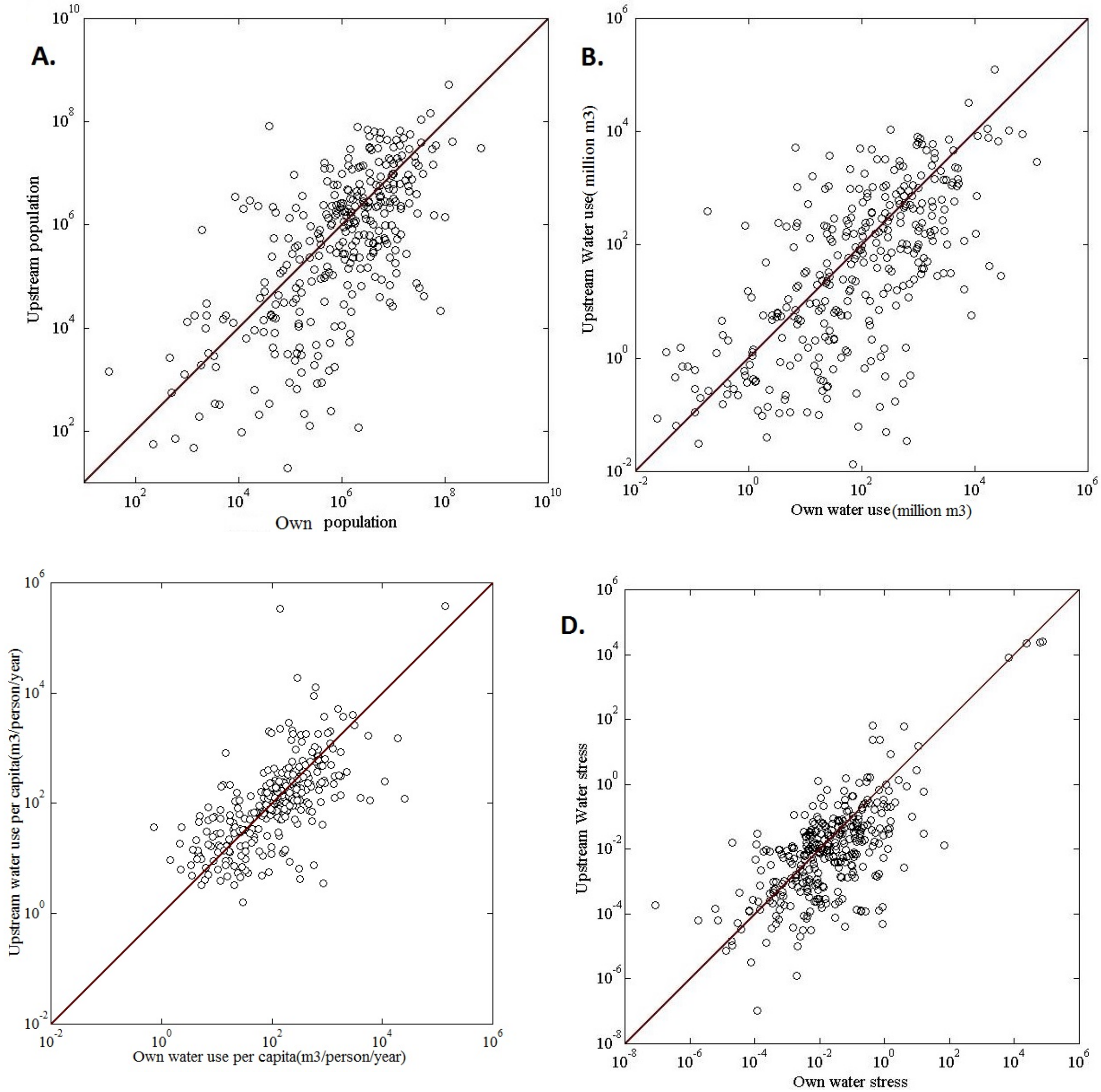


Figure 3 own vs. upstream. A. Population (billion); B. Water use (million m³). C. Per capita water use (m3/person/year); D. water stress

3.3 Water stress due to own water use

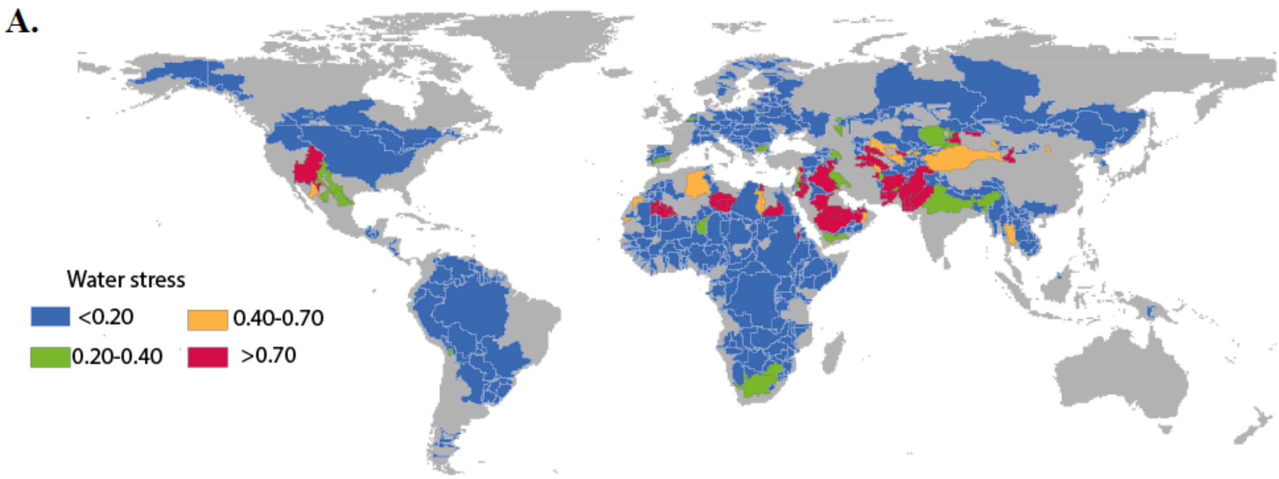
According to the calculations 34% (956 million people) of total transboundary population was facing some level of water stress due to their own water use (i.e. excluding the possible upstream water use). About 10% of the total transboundary population is living in areas that suffered from extreme water stress; while 3% and 20% people were living in areas facing high and moderate stress respectively (Table 3). About 16% of the total transboundary surface area was suffering moderate to extreme water stress due to their own water use (Table 4).

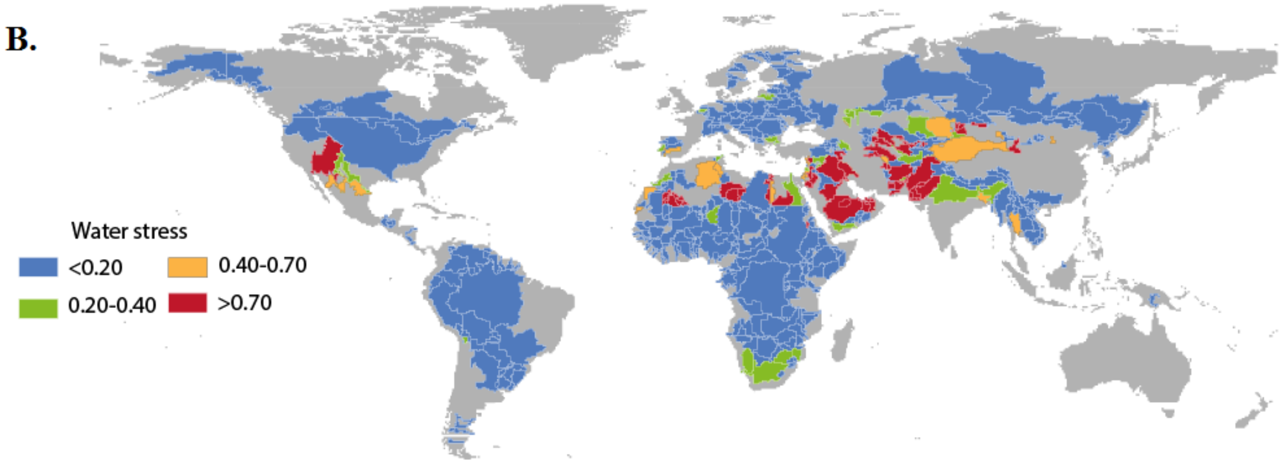
Extreme stress due to the sub-basin's own water use was identified mainly in the Middle East, Asia (Central Asia and Southern Asia), Northern parts of Africa and in North

America (Figure 4A). In Asia extreme water stress was identified in basins such as Indus, Helmand, Jawai, Tigris, Al Batin. In North America extreme stress was identified only in Colorado River basin; while in Europe almost all the transboundary basins are under no stress zone. In Northern parts of Africa some basins like Al Maks, Fezzan are identified to have extreme water stress. In most of the basin, there water stress is extreme mainly in the most downstream part of the basins except some few basins, such as the whole area of basin Jawai in Central Asia, Colorado, and Al Batin.

Table 3 Population under different water stress categories with consideration of own water use only or own and upstream water uses.

Water Availability approach	Population not under water Scarcity ($\times 10^6$)	Population under water scarcity($\times 10^6$)			
		Moderate Water Stress (0.2<WSI<0.4)	High Water stress. (0.4<WSI<0.7)	Extreme water Stress. (WSI>0.7)	Total under Water stress
Own water use	1915 (66%)	580 (20%)	77 (3%)	298 (10%)	955 (34%)
Own and upstream water uses	1721 (60%)	632 (22%)	188 (7%)	336 (12%)	1149 (40%)





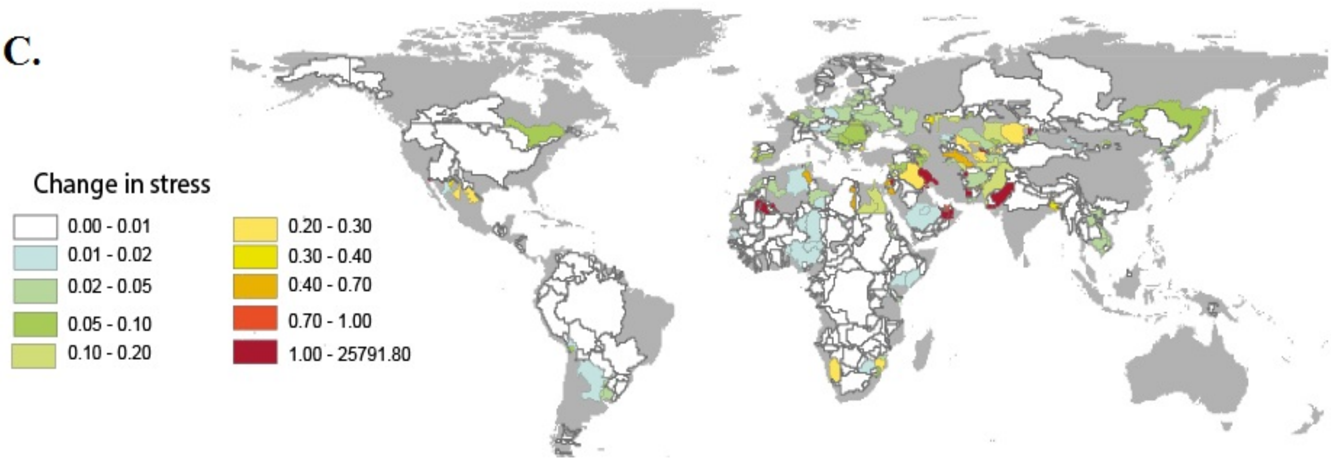


Figure 4: Water Stress mapped A) Basin's own water use. B) Basin's own and upstream water use. C) Change in stress level due to upstream water use.

Table 4 Area under different water stress categories with consideration of own water use only or own and upstream water use.

Water Availability approach	Area not under water stress (Million square kilometers)	Area under water stress(Million square kilometers)			
		Moderate stress. (0.2<WSI<0.4)	High stress (0.4<WSI<0.7)	Extreme stress (WSI>0.7)	Total under Water stress
Own water use	52.51(84%)	3.07(5%)	2.52(4%)	4.45(7%)	10 (16%)
Own and upstream water uses	48.97(78%)	3.73(6%)	4.66(7%)	5.19(8%)	14 (21%)

3.3. Impact of upstream water use on stress level

In some basins, water stress increased quite significantly when the upstream water use was taken into account. According to the calculations 328 sub-basins were identified where there was some change in stress while in 276 sub-basins no change was identified (Figure 5).

Results indicate that in 79 sub-basins the change in WSI (water stress index) due to upstream water use was above 0.05, 41 sub-basins where change was above 0.2 and 19 sub basins where was above 1 (Figure 4C). Altogether 34 sub-basins 'jumped' to the next category of water stress. The most downstream sub-basins of Colorado and As Summan (Mexico and United Arab Emirates parts of basins) entered from no stress zone to the extreme stress zone while the most downstream sub-basins in Ganges, Jordan and Asi (Bangladesh, West Bank, and Turkey parts of the basins) entered from no stress zone to the moderate stress zone when upstream basin water uses were considered (Figure 4B).

The results indicate that population under some level of stress increased from 950 to 1149 million people (6 percentage points) due to upstream water use (Table 3). Population under the extreme stress zone increased by 2 percentage points while population under high and moderate stress zone increased by 4 and 2 percentage points respectively. Total transboundary area under water stress increased by almost 6 percentage points due to upstream countries water use (Table 4).

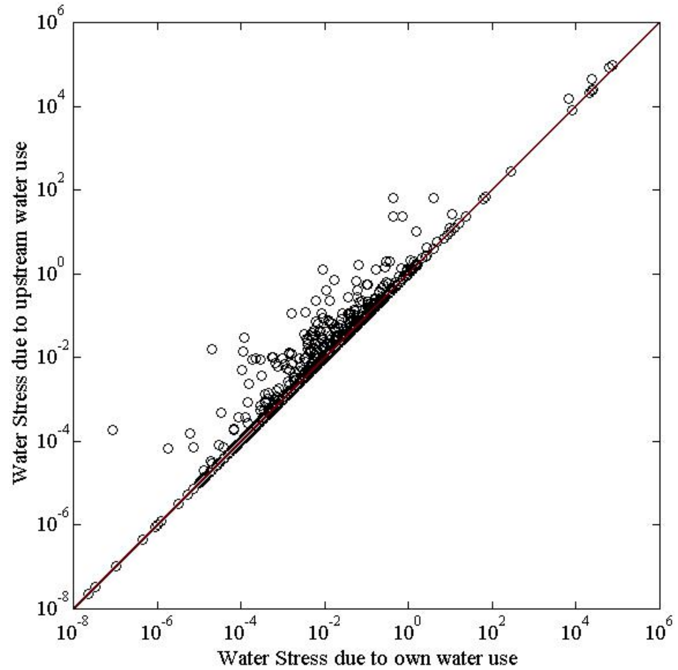


Figure 5: Water stress due to own water use vs own and upstream water uses.

4. Discussion

In this study I assessed the change in water stress level due to upstream water use in the transboundary river basin. The results indicate that population under water stress zone increased from 34% to 40% due to upstream water use while the WSI (water stress index) increased at least 0.05 in 79 sub-basins (Figure 5). Increase in stress was considerable particularly Central Asia and in the north-eastern part of Africa (Figure 4C). I further found that 34 sub-basins entered to the next water stress level because of their upstream water consumption, which suggests that upstream water use has substantial impact on the water stress level in downstream parts of the basins. Such findings are important for international water bodies, where, 'equitable 'water allocation is at the center of most water conflicts.

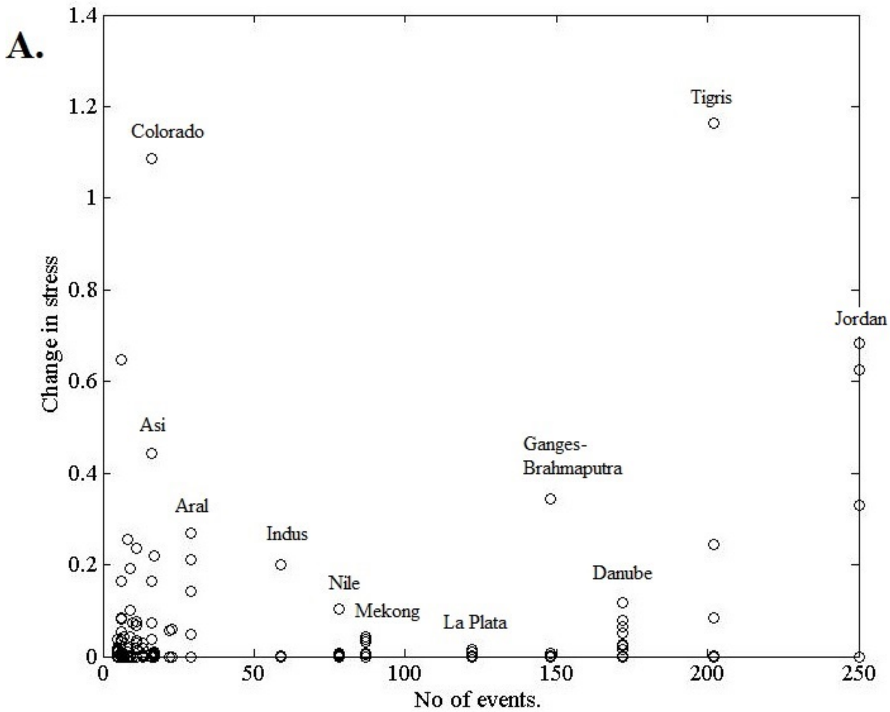
4.1. Upstream water use: reasons for Conflict?

River basins with upstream/downstream relationship are identified to have increased risks of conflicts (Brochmann, Gleditsch 2012), while history shows evidence that cooperation is more frequent than conflicts over shared waters (Wolf, 1998). To assess whether there is a link between increased water stress due to upstream water use and the occurrence of conflictive and cooperation events in the transboundary river basins, I compared my findings with International water Event Database (1950-2008) by Oregon State University (Oregon State University. 2007).

Basins that have at least five events (both cooperative and conflictive events were considered) were selected from the 'Event database' (Oregon State University. 2007) for this analysis. When the change in stress level per basin (due to upstream water use) was compared with the number of events per basin, no direct relationship between these two variables was found (Figure 6A). However, in many basins with high number of events, also the stress index increased considerably due to upstream water use.

For example, change in stress was high in many of the Tigris River sub-basins and also the number of events in this basin was among highest (202 events of which 48% were Cooperative events). On the other hand, in case of Danube River Basin change in sub-basins' stress was rather low compared to Tigris but still high number of events (172 events of which 55% were cooperative events) occurred there. Highest number of events (250 events of which only 44% were cooperative events) occurred in the Jordan river basin, and although the change in stress is considerable in this basin, it is rather low compared to Colorado Basin where only 16 events occurred of which 69% were cooperative events.

Therefore, while the increased stress due to upstream water use might explain some of the high events, there are many other factors too influencing on this.



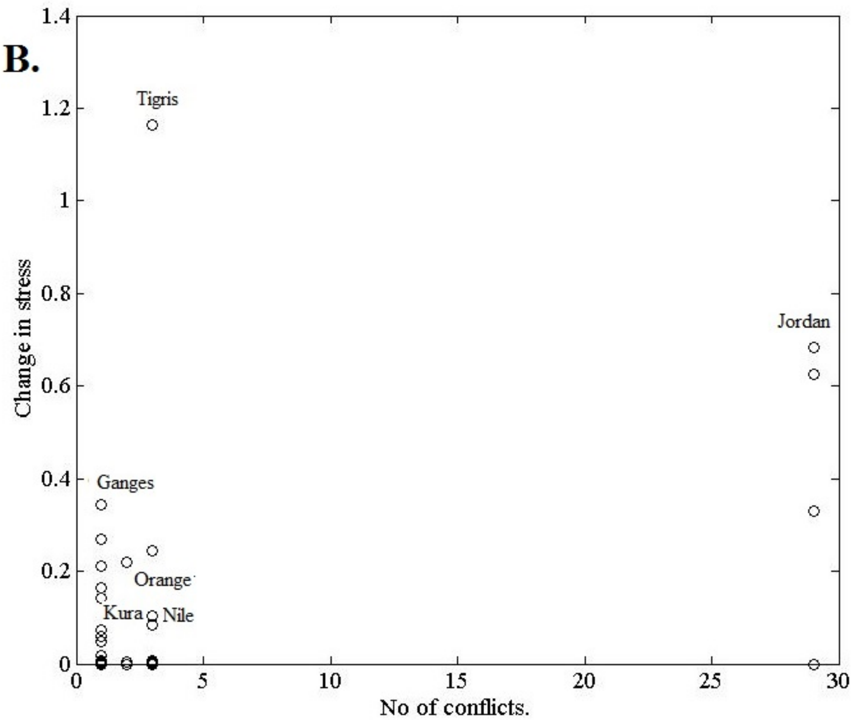


Figure 6 A.Change in stress vs No of events; B. Change in stress vs No of conflicts.

Basins with high number of conflictive events were also compared with the result of this study to assess the connection between increased water stresses due to upstream water consumption to the frequency of conflicts among the basins (Figure 6A). Jordan River Basin is been identified as the basin with highest number of conflictive events and rather strong impact on water stress too, while Tigris shows considerably high change but not many conflict events. In case of both Jordan and Tigris, the reasons for water conflict are mainly politics; the country holding more power and military usually controls the bulk of the river flow (Rosenthal, Sabel 2009, Qarkoglu, Eder 2001).

If we look at the past conflicts over water, dam construction, degradation of water quality, neglect or non-acceptance of existing treaty provision, politics over water are the main reasons for transboundary water conflicts (UN Water 2013). Again, high population growth, urbanization, increasing water pollution, over-abstraction of groundwater, water-related disasters, and climate change will keep swelling the tension among the riparian countries (Asian Development Bank, 2013). The complexity in the relationship of two riparian countries over water depends on multiple factors. Politics, economic condition may lead two riparian countries to cooperate or enter conflict, as well as climate, geography, water availability, etc. So, the reasons for conflict among the upstream/downstream countries cannot define by only one factor such as upstream water use, although it might be one important factor in it. This study thus provides detail information of that for all the transboundary river basins in the world and the results can be used in the future studies which are able to take more factors into account when assessing the relationships within a transboundary river basin.

4.2 Limitations and future research needs

In this study agricultural, industrial and domestic water uses were taken in to account for the calculation of water stress. While environmental water requirements are taken into account in the water stress methodology (assumption that environment needs are 30%), those could be taken into account much better (Gerten, Hoff et al. 2013). Moreover, upstream water use impacts also on seasonal flow regime, which is not taken into account in this calculation. Therefore, seasonal impacts of upstream water use on water stress and environmental flows should be studied in future research.

Water quality has an impact on the region’s water availability too (UNEP-DHI 2011). The volume of usable water resources in downstream sub-basin might be reduced due to the industrial or domestic pollution in upstream sub-basin(s). This aspect of water scarcity was not considered in this study and would need further research in the future, as this is a growing problem in various parts of the globe.

Finally, identifying upstream and downstream parts of a basin was difficult in some of the basins, particularly in dry areas, as there is no international database that determines the upstream variables for a basin. There are also a great number of riparian countries that does not have any clear upstream/downstream relationship (Delbourg, Strobl 2012). These issues should, therefore, be considered in future water stress analysis.

5. Conclusions

In this study, I compared the change in water stress level in the transboundary river basins due to upstream water consumption. Further, I compared my results with International water Event Database (1950-2008) to assess the possible connection between increased stress due to upstream water use and the occurrence of collaborative and conflict events on the international river basins.

I found that upstream water use increased the population under water stress level by 6 percentage points (194 million people). This stress increased most in Asia (central and north-east parts), Africa and some parts of Europe. Although no direct relationship was found between change in stress and occurrence of events in transboundary river basins, the comparison provided some interesting insights on the issue and my results could be combined with other factors to further assess their role in conflict and collaborative events in transboundary river basins.

My findings provide much needed information of the upstream water consumption impact on downstream water stress and these results can be used when negotiating the water extractions within a basin and adopting proper means of regulating water extraction in different parts of a basin. The results would further contribute to the discussions on 'equity' in case of transboundary river basins because this analysis might shed light on how to divide water among upstream/downstream countries while coordinating water management along shared rivers.

References

Afroz, R., and Rahman, M. A. (2013). "Transboundary River Water for Ganges and Teesta Rivers in Bangladesh: An Assessment." *Global Science and Technology Journal*, 1(1), 100-111.

Asian Development Bank. (2013*). Asian Water Development Outlook 2013:Measuring Water Security in Asia and the Pacific,* ADB, Philippines.

Brochmann, M., and Gleditsch, N.,P. (2012). "Shared Rivers and Conflict – A Reconsideration*." Political Geography*, 31(8), 519-527.

Delbourg, E., and Strobl, E. (2012). "Cooperation and Conflict between Upstream and Downstream Countries in African Transboundary Rivers." *Dpt. of Economics, Ecole Polytechnique, France* .

Domnita, M., Craciun, A. L., Haidu, I., Magyari-Saska, Z. (2010). "GIS used for Determination of the Maximum Discharge in very Small Basins(Under 2 km 2)." *WSEAS Transactions on Environment and Development*.6(6), 1-20.

Dixen,T.,H.,. (1995). "the Ingenuity Gap: Can Poor Countries Adapt to Resource Scarcity?" *Population and Development Review*, 21(3), 587-612.

Dixen, T. H. (1994). " Environmental Scarcities and Violent Conflict: Evidence from Cases " *International Security,* 19, 5-40.

Falkenmark, M., Berntell, A., Jägerskog, A., Lundqvist, J., Matz, M., Tropp, H. (2007). "On the Verge of a New Water Scarcity: A Call for Good Governance and Human Ingenuity." *SIWI Policy Brief*, (SIWI).

Falkenmark, M., Lundqvist , J., Widstrand, C. (1989). "Macro-Scale Water Scarcity Requires Micro-Scale Approaches." *Nat. Resour. Forum*, 13, 258-267.

Flakenmark, M. (1997). "Meeting Water Requirements of an Expanding World Population." *Philos Trans R Soc Lond B Biol Sci*., 352, 929-936.

Gerten, D., Hoff , H., Rockström, J., Jägermeyr, J., Kummu, M., Pastor, A. V. (2013). "Towards a Revised Planetary Boundary for Consumptive Freshwater use: Role of Environmental Flow Requirements." *Current Opinion in Environmental Sustainability*, 5(6), 551-558.

Gikonyo, J. K. (1997). "River water abstraction monitoring for the ewaso Ng'iro river basin, kenya*." Paper Presented at the SPPE Workshop*, Madagascar, 2–6 June 1997.

Giordano, M. A., and Wolf, T. A. (2013). "Sharing Waters: Post Rio International Water Management." *Natural Resources Forum,* 27, 163-171.

Gleick, P. H. (1993). "Water and Conflict." *International Security*, 18(1), 79-112.

Graversen, M. K., and Heberger, M. (2011). *"Regulating Water Extraction in a River Basin with Upstream-Downstream Communities."* FOI working paper 2011/2, Institute of Food and Resource Economics, University of Copenhagen.

Growing, b. (2011). "Growing blue." <http://growingblue.com/wp-content/uploads/2011/04/Growing-Blue.pdf> (3/31, 2014).

Grübler, A., O'Neill, B., Riahi, K., Chirkov, V., Goujon, A., Kolp, P., Prommer, I., Scherbov, S., Slentoe, E. (2007). "Regional, National, and Spatially Explicit Scenarios of Demographic and Economic Change Based on SRES." *Technological Forecasting and Social Change*, 74(7), 980-1029.

Hameeteman, E. (2013). "*Future Water (in)Security: Facts, Figures, and Predictions*." Global Water Institute. Brussels.

Intelligence Community Assessment. (2nd February2012). " Global Water Security." (Office of Director of National Intelligence,United States of America).

Islam, M. S., Oki, T., Kanae, S., Hanasaki, N., Agata, Y., Yoshimura, K. (2007). "A Grid-Based Assessment of Global Water Scarcity Including Virtual Water Trading." *Water Resource Manage*, 21, 19-33.

Jägerskog,A.,andZeitoun,M.(2009). *Getting Transboundary Water Right: Theory and Practice for Effective Cooperation.* 25th Ed., SIWI, Stockholm.

Klein Goldewijk, K., Beusen, A., Janssen, P. (2010). "Long-Term Dynamic Modeling of Global Population and Built-Up Area in a Spatially Explicit Way: HYDE 3.1." *The Holocene*, 20(4), 565-573.

Kummu, M., Ward, P. J.,de Moel,H.,Varis,O. (2010). "Is Physical Water Scarcity a New Phenomenon? Global Assessment of Water Shortage Over the Last Two Millennia." *Environmental Research Letters Email Alert RSS Feed*, 5(3).

Mehtonen, K. (2008). "Do the Downstream Countries Oppose the Upstream Dams?" *Modern Myths of the Mekong,* Helsinki University of Technology, Helsinki, Finland, 161-173.

Moellenkamp, S. (2007). "The “WFD-Effect” on Upstream-Downstream Relations in International River Basins – Insights from the Rhine and the Elbe Basins." *Hydrology and Earth System Sciences Discussions*, 7, 1407-1428.

Oregon State University. (2007). "Transboundary freshwater dispute database (TFDD)." <http://www.transboundarywaters.orst.edu/> (8/21, 2014).

Ouda, O. (2013). "Towards Assessment of Saudi Arabia Public Awareness of Water Shortage Problem." *Resources and Environment*, 3(1), 10-13.

Qarkoglu, A., and Eder, M. (2001). "Domestic Concerns and the Water Conflict Over the Euphrates-Tigris River Basin." *Middle Eastern Studies*, 37(1), 41-71.

Rahman, M. M. (2005). "Integrated Water Resources Management in the Ganges Basin: Constraints and Opportunities." Thesis for Licentiate of Science in Technology,Helsinki University of Technology, Finland .

Ravnborg, H. M. (2004). *Water and Conflict Conflict Prevention and Mitigation in Water Resources Management*. 2nd Ed., Danish Institute of International Studies,DIIS, Copenhagen.

Rockström, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S., Gerten, D. (2009). "Future Water Availability for Global Food Production: The Potential of Green Water for Increasing Resilience to Global Change." *Water Resources Research*, 45(7), 1-16.

Rosenthal, E., and Sabel, R. (2009). "Water and Diplomacy in the Jordan River Basin." *Israel Journal of Foreign Affairs*, 2(3), 95-115.

Schewe , J., Heinke, J., Gerten, D., Haddeland, I., Arnell, N. W.,., Clark , D. B., Dankers, R., Eisner , S., Fekete , B. M., Colón-González , F. J., Gosling , S. N., Kim, H., Liu , X., Masaki , Y., Portmann, F. T., Satoh , Y., Stacke, T.,., Tang, Q., Wada, Y., Wisser , D., Albrecht , T., Frieler, K., Piontek, F., Warszawski, L., Kabat, P. (2014). "Multimodel Assessment of Water Scarcity Under Climate Change." *Proceedings of the National Academy of Sciences*, 111(9), 3245-3250.

Schlosser, C. A., Strzepek, K., Gao, X., Gueneau, A., Fant, C., Paltsev, S., Rasheed, B., Smith-Greico, B., Blanc, É., Jacoby, H. D., Reilly, J. M. (2014). *The Future of Global Water Stress: an Integrated Assessment,* Joint Program Report Series, Cambridge.

UN Water. (2013). "Transboundary waters." <http://www.unwater.org/topics/transboundary-waters/en/> (8/6, 2014).

UNEP-DHI. (2011). "Methodology for the GEF Transboundary Waters Assessment Programme." *Methodology for the Assessment of Transboundary River Basins*,*UNEP*, 4, 8-147.

Votrin, V. (2003). "Transboundary Water Disputes in Central Asia: Using Indicators of Water Conflict in Identifying Water Conflict Potential." Master's thesis, Vrije Universiteit Brussel.

Wada, Y., van Beek, L. P. H., Bierkens, M. F. P. (2011). "Modelling Global Water Stress of the Recent Past: On the Relative Importance of Trends in Water Demand and Climate Variability." *Hydrology and Earth System Sciences*, 15, 3785-3808.

Wada, Y., and Heinrich, L. (2013). "Assessment of Transboundary Aquifers of the world—vulnerability Arising from Human Water use." *Environmental Research Letters*, 8(2), 024003.

Wada, Y., van Beek, L. P. H., Wanders, N., Bierkens, M. F. P. (2013). "Human Water Consumption Intensifies Hydrological Drought Worldwide." *Environmental Research Letters*, 8(3), 034036.

Wolf , T.,A. (1998). "Conflict and Cooperation Along International Waterways." *Water Policy*, 1, 251-265.

Wolf, A. T. (2007). "Shared Waters: Conflict and Cooperation. Annual Review of Environmental Resources." *Annual Review of Environmental Resources*, 32, 241-269.

Wolf, A. T. (2004*). Freshwater Transboundary Dispute Database*, Corvallis, OR, USA: Oregon State University.

Wolf, A. T., Yoffe, S. B., Giordano, M. (2003). "International Waters: Identifying Basins at Risk." *Water Policy*, 5, 29-60.

Wolf, A. T. (1999). "Criteria for Equitable Allocations: The Heart of International Water Conflict." *Natural Resources Forum*, 23(1), 3-30.

World Data Bank II. 1980. Global river network. CIA, U.S. government. Available online at http://www.evl.uic.edu/pape/data/WDB/.

World Water Vision. (2000). *A Water Secure World:Vision for Water, Life,and the Environment*, 1st Ed., Earthscan Publications Ltd, London,UK.

Yuldasheva, G., Hashimova, U., Callahan, J. (2010). "Current Trends in Water Management in Central Asia." *The Peace and Conflict Review*, 5(1), 1-13.

Zeitoun, M., and Mirumachi, N. (2008). "Transboundary Water Interaction I: Reconsidering Conflict and Cooperation." *Int Environ Agreements,* 8, 297-316.